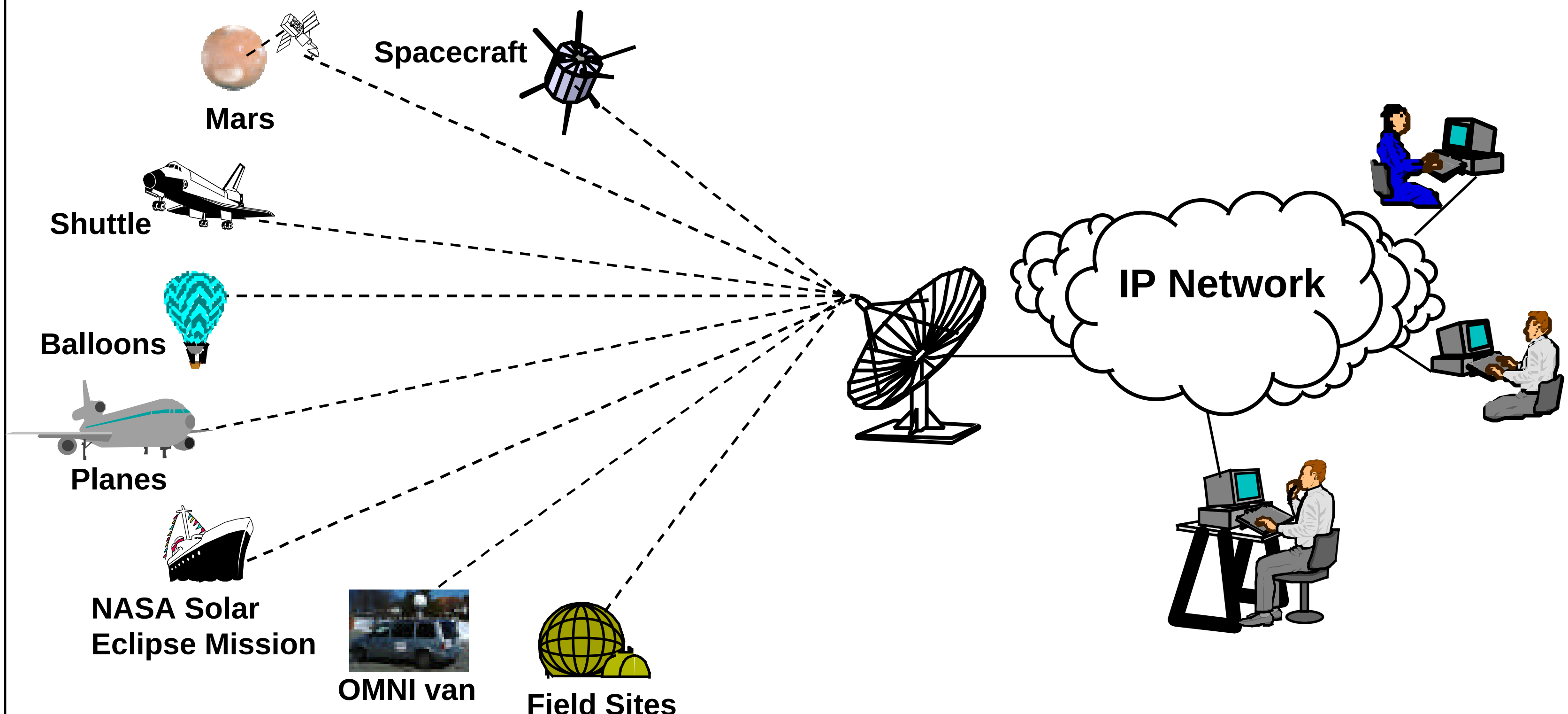
Operating Missions as Nodes on the Internet (OMNI)



February 2000

Standard IP Communication Concept

- The NASA/GSFC Codes 451, 560, 581, 582 and 588 are pursuing projects that demonstrate the feasibility of using COTS Internet hardware and software to support NASA science missions such as satellites, balloons, and remote field sites
- The OMNI prototype is being developed and demonstrated to remove myths and misconceptions about the Internet Protocol “not working” in space
- The basic approach is to make all remote science systems “nodes on a network”
- Using an IP network backbone provides the following benefits:
  - Scientists are familiar with the Internet and its collaboration capabilities
  - No special communication hardware is needed at ground systems or end users
  - A wide range of COTS hardware and software solutions exist and their development, debugging and ongoing maintenance is paid for by someone else
  - Collaborative science missions are possible since IP provides a common communication mechanism between science systems
- Data for most NASA missions is delivered over IP backbones today (TDM or CCSDS frames in Nascom 4800 bit blocks delivered over UDP/IP by Nascom and DSN)

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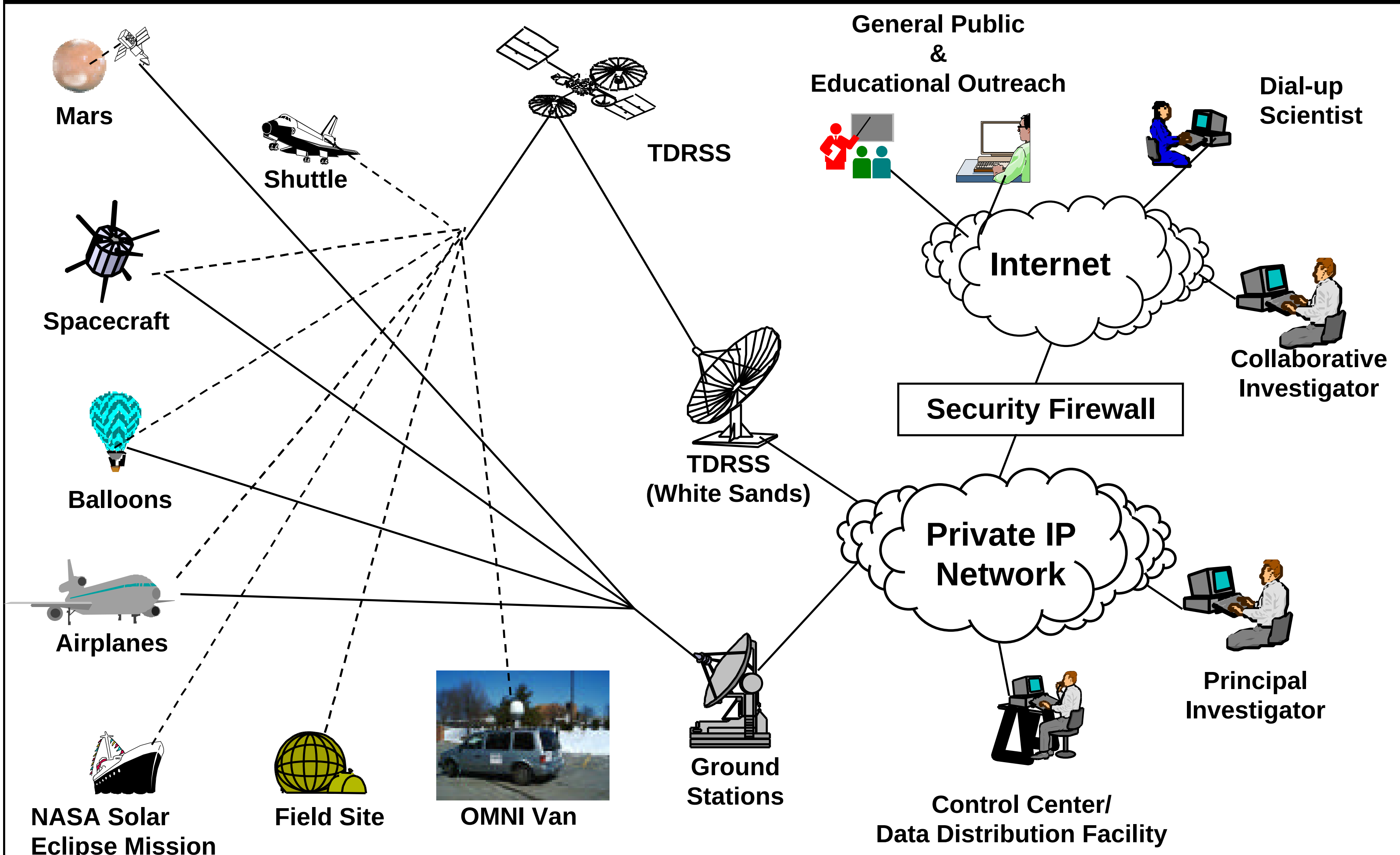
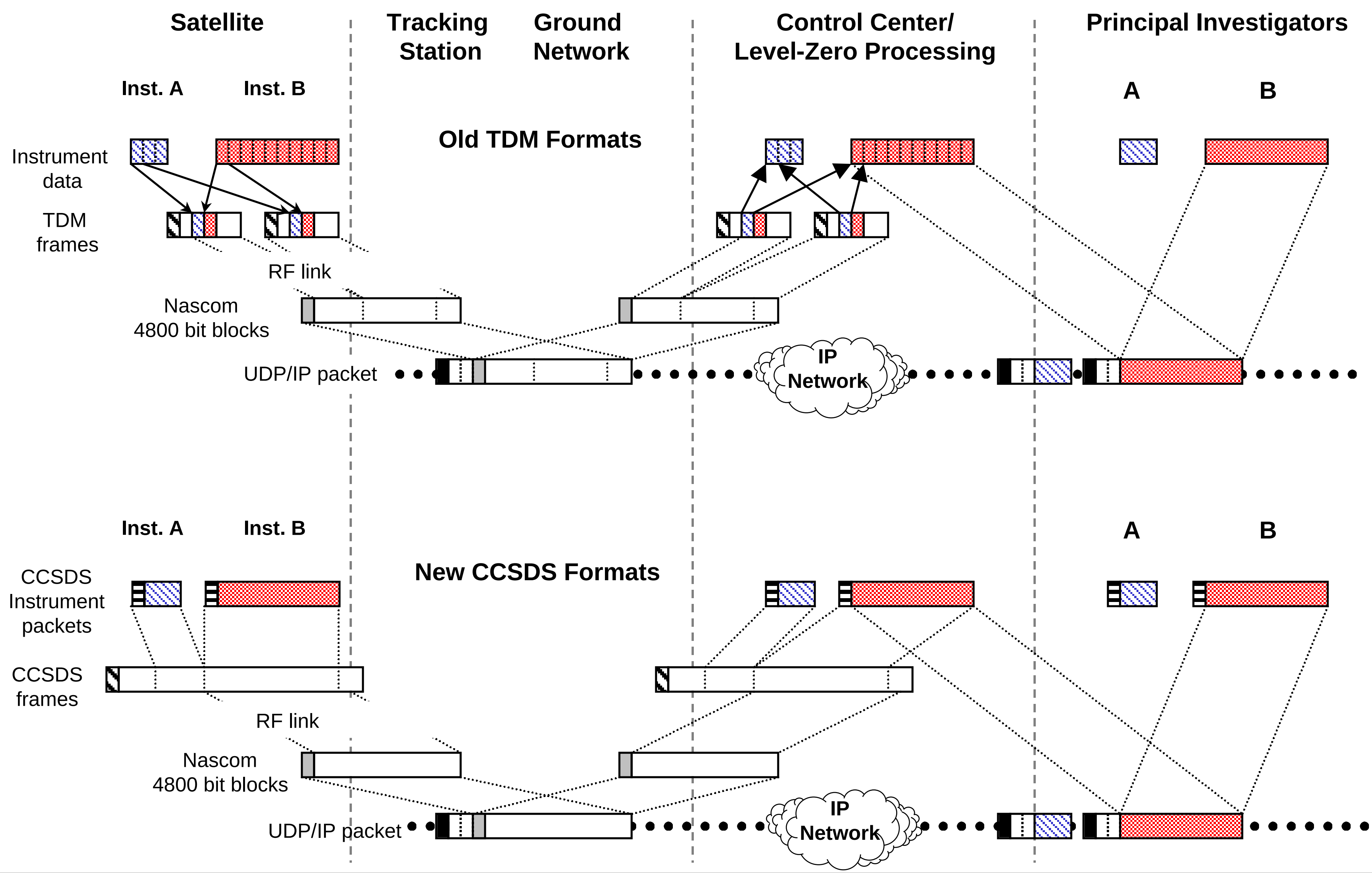


Current Mission Data Flows

- Old satellites (time division multiplex (TDM) frames)
  - Instrument data records are sampled in small pieces
  - Samples commutated across multiple communication frames
  - Frames inserted into Nascom 4800 bit blocks at ground tracking station
  - Nascom blocks delivered to control centers and level-zero processor (LZP) via IP network
- Newer satellites (CCSDS conventional and AOS formats)
  - Instrument records generated in CCSDS packet formats
  - CCSDS packets multiplexed into CCSDS frames
  - CCSDS frames inserted into Nascom 4800 bit blocks at ground tracking station
  - Nascom blocks delivered to control centers and level-zero processor (LZP) via IP network
- Some new missions
  - CCSDS frames synchronized at tracking station and delivered to control centers and LZP via IP
- Custom built front-end processors at each satellite's control center and LZP system synchronize data to locate frames and decommutate data or extract packets
- Data must be captured and reformatted for further distribution to scientists and end-users
- A large amount of custom and expensive ground communication equipment must be built, operated, and maintained to support NASA unique formats
- Communication between satellites and cross-support between missions is very difficult or impossible

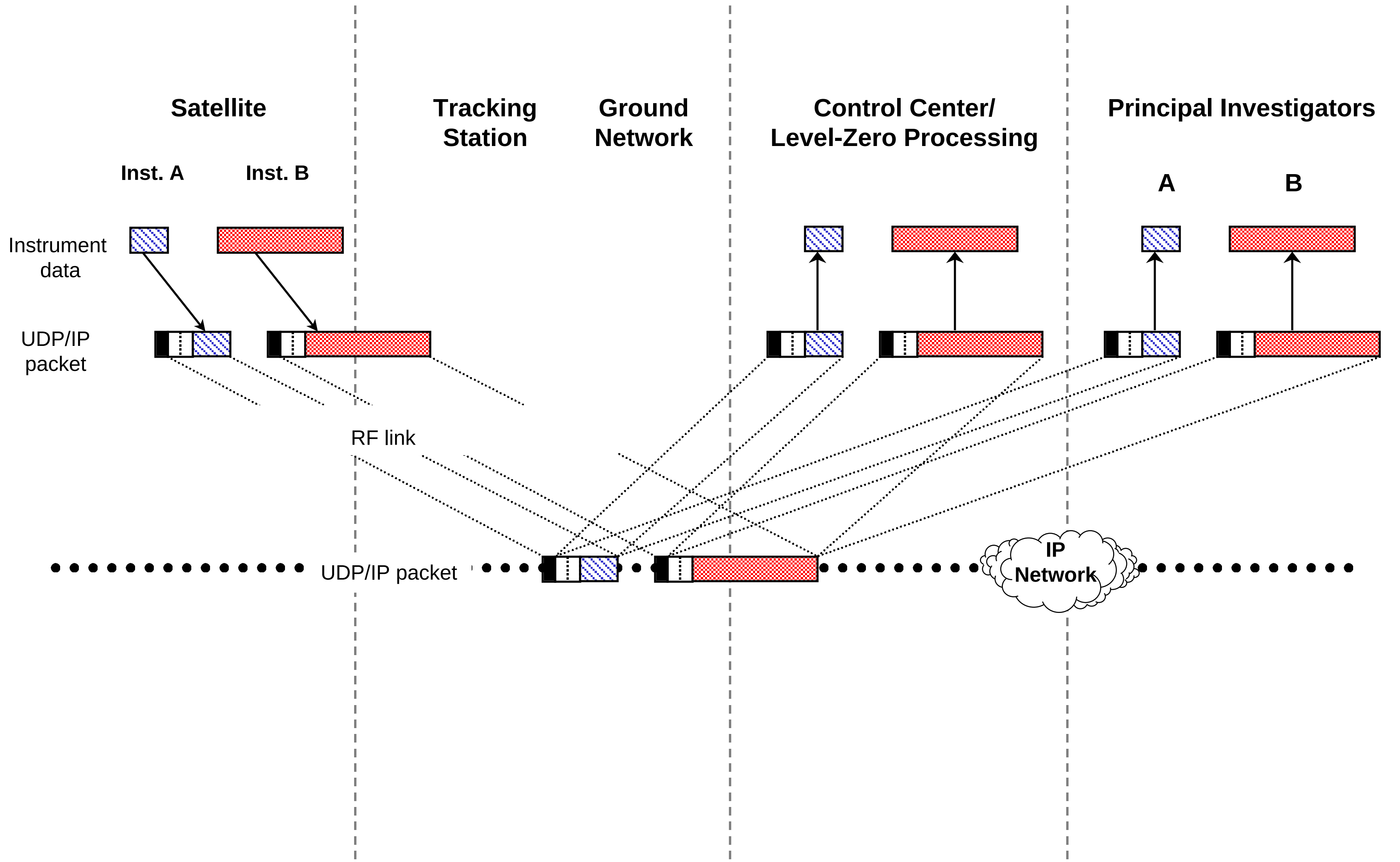
Current Mission Data Flows



IP Based Mission Data Flows

- Instrument records are generated, written to onboard files if desired and IP network addresses are added to realtime data to identify a destination
- Connection-less UDP/IP delivery is used for “unreliable” data delivery (unaffected by propagation delay and errors, operates over a simplex communication path)
- Connection-oriented TCP/IP is used for “reliable” data delivery (sensitive to propagation delay and errors, requires a duplex communication path)
- IP packets flow through RF communication links to tracking stations and are routed across Internets using standard networking equipment (Frame Relay/HDLC framing)
- IP packets can flow unmodified from an instrument to any end user (end user can be control centers, LZP, scientists, or other satellites, balloons, etc.)
- No custom processing facilities are required to reformat data for basic delivery
- Files of data from each instrument can flow directly to scientists without requiring intermediate processing
- The reduction in custom hardware, software and intermediate processing systems results in significant cost savings and quicker data delivery for a mission

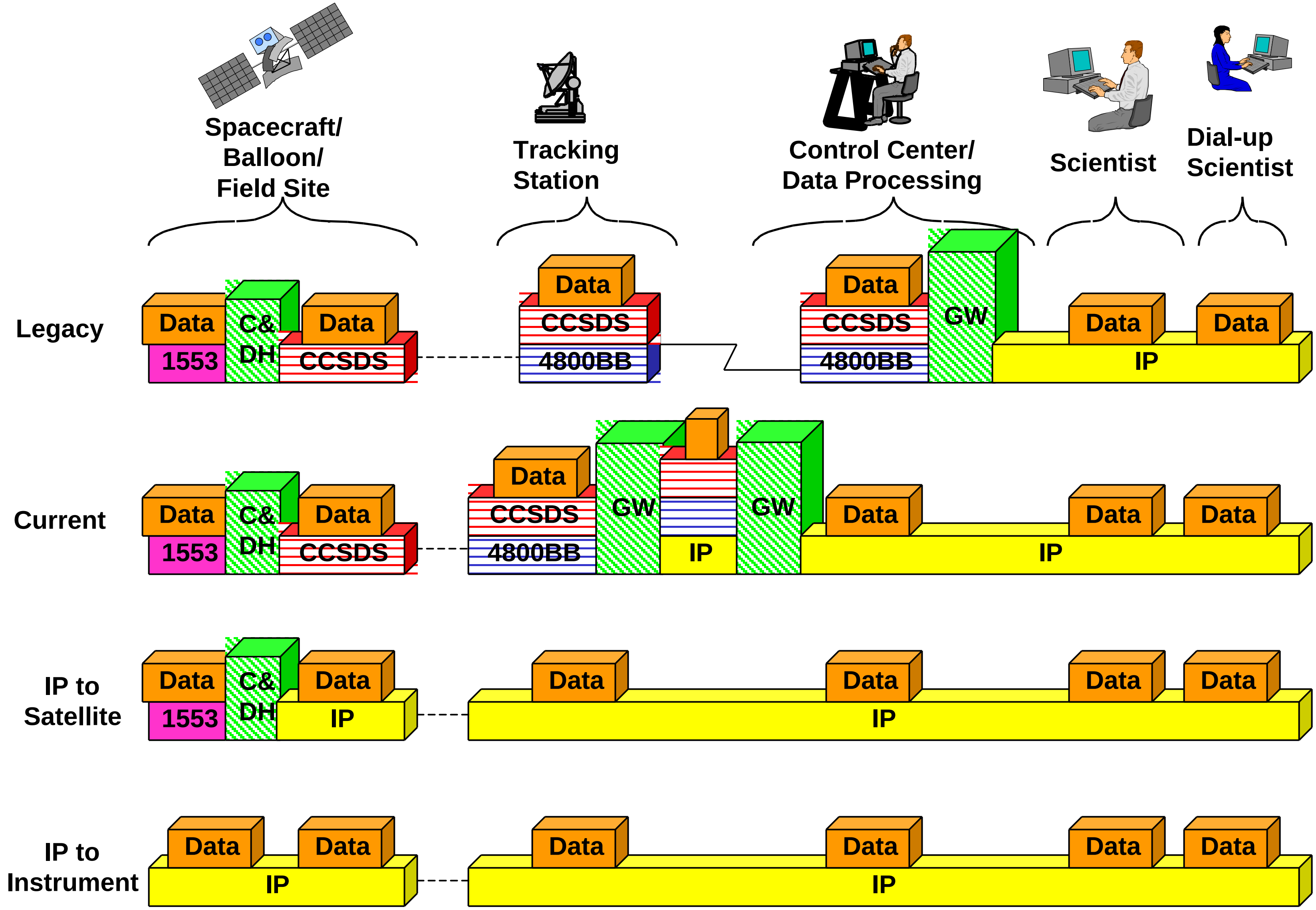
IP Based Mission Data Flows



End-to-End Space Link Evolution

- Legacy NASA communication systems used custom NASA protocols and equipment because there were no other options
- Current NASA satellite communication systems use a mix of custom and COTS network technology, but there is still lots of room for improvements
  - Custom communication protocols require expensive development, maintenance and operation of custom gateways and processing systems
  - Current satellite protocols do not provide the ease of use and addressing capabilities to support new, collaborative science missions
- Future "IP to the Satellite" concepts use COTS network technology and protocols to the C&DH system on the spacecraft
  - This eliminates custom gateways and protocols and reduces development, maintenance and operations costs while also enabling collaborative science missions
- Future "IP to the Instrument" concept extends IP onboard the satellite
  - This enables direct access from instruments to scientists to further reduce intermediate processing systems and "non-science" costs for missions
- Legacy spacecraft still supported with existing systems and protocols

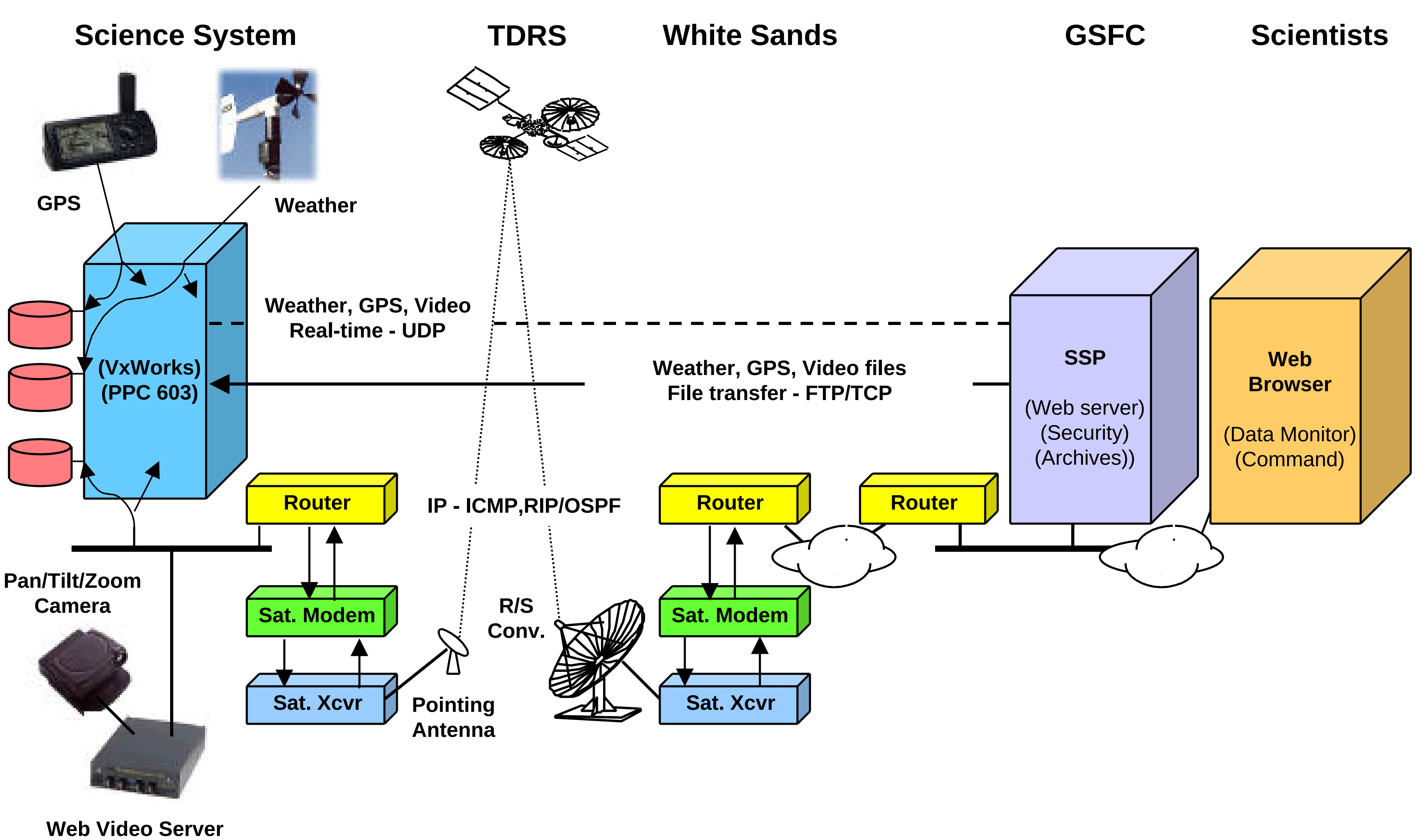
End-to-End Space Link Evolution



End-to-End IP Communication Prototype

- The basic goal of the OMNI prototype is to demonstrate that IP works over space links and to investigate issues of LAN based satellites, balloons, etc.
- IP provides end-to-end data delivery and makes the science system a “node on a network”. Various upper layer protocols can be used for file transfers, status monitoring and commanding
- The OMNI prototype consists of a simulated satellite (VME chassis, PPC 603 processor, VxWorks real-time OS) with 3 “science instruments”
  - GPS receiver (RS-232 interface)
  - Weather station (RS-232 interface)
  - Video webserver (Ethernet interface, multiple cameras)
- The prototype demonstrates real-time and playback data similar to a real satellite
  - Real-time data - records sent in real-time using UDP/IP/HDLC
  - Playback data - records logged to files for later transfer via FTP/TCP/IP/HDLC
- Commanding can be done via UDP or TCP
- The laboratory demonstration uses a simulated RF link (Adtech channel simulator)
- Outdoor demos use a TDRSS RF link for demonstration of full mobile, intermittent access to the science equipment

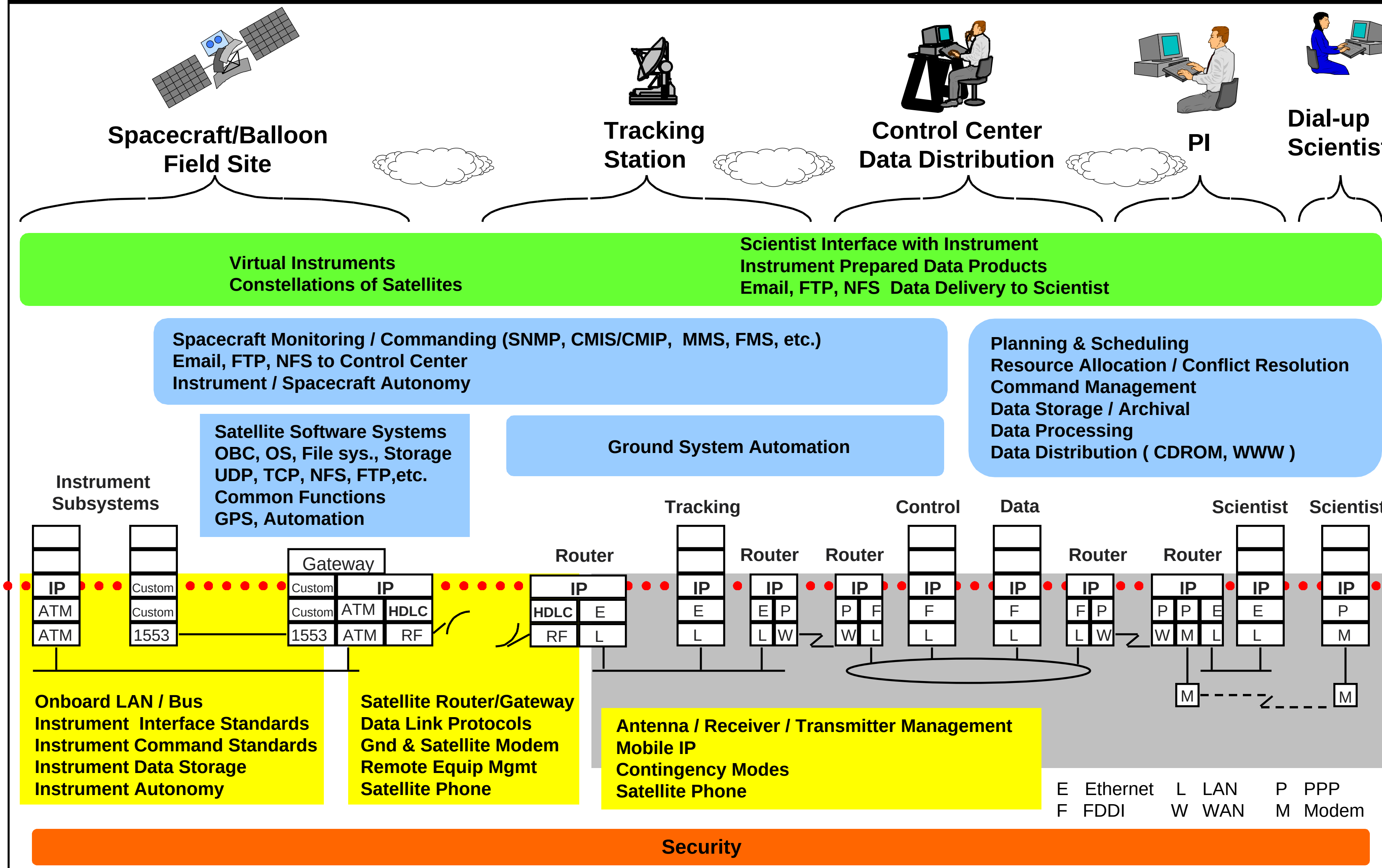
End-to-End IP Communication Prototype



End-to-End Satellite Networking Issues

- The key component in the architecture is the IP network layer and its basic ability to deliver packets between any network source and destination
- Lower layer key issues (communication links support common IP packet delivery)
  - IP network exists between all ground systems
  - Need to adopt industry standards for serial interfaces over science system RF links
  - Standard transceiver interfaces are needed (TDRSS project is working on new transceivers)
  - Satellite LAN and router technology is the first step in implementing IP onboard satellites
- Upper layer key issues (IP provides a common interface to upper layer software)
  - Standard satellite operating systems are needed which support standard networking protocols (i.e. FTP/TCP/UDP/IP) and file systems for separating instrument and housekeeping data
  - Work is needed in structuring satellite subsystems with more distributed processing concepts so they can operate as "nodes on a network"
- The OMNI prototype has demonstrated live data flows over TDRSS using standard IP
- The OMNI prototype was used Aug. 11, 1999 on a cruise ship in the Black Sea to return live images and weather information on the last total solar eclipse of the millennium.
- Work is underway to perform IP flight tests with the UoSAT-12 spacecraft in 1Q2000
- Discussions are underway with commercial software and hardware manufacturers to develop the missing components for end-to-end IP support

End-to-End Satellite Networking Issues



Acronyms

ATM	Asynchronous Transfer Mode
C&DH	Command and Data Handling
CCSDS	Consultative Committee for Space Data Systems
CMIP	Common Management Information Protocol
CMIS	Common Management Information Services
COTS	Commercial Off-The-Shelf
CSC	Computer Sciences Corporation
DSN	Deep Space Network
FDDI	Fiber Distributed Data Interface
FTP	File Transfer Protocol
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
HDLC	High-level Data Link Control
ICMP	Internet Control Message Protocol
IP	Internet Protocol
IPSec	IP Security
LAN	Local Area Network
LZP	Level-Zero Processing
MMS	Manufacturing Messaging Specification
NASA	National Aeronautics and Space Administration
NFS	Network File System
OS	Operating System
OSPF	Open Shortest-Path First
PI	Principal Investigator
Power	Performance Optimization With Enhanced RISC
PPC	Power Personal Computer
PPP	Point-to-Point Protocol
RF	Radio Frequency
RIP	Routing Information Protocol
SMTP	Simple Mail Transfer Protocol
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
TDM	Time Division Multiplex
TDRSS	Tracking and Data Relay Satellite System
UDP	User Datagram Protocol
VME	Versabus Modula Europa
VPN	Virtual Private Network
WAN	Wide Area Network
WFF	Wallops Flight Facility
WWW	World Wide Web